WOOD. (H.C.)

a botanical excursion in my office. —

phia; 29, Arachnoidiscus; 30, Grammatophora; 31, Biddulphia,—a, two frustules, still enclosed by the "connecting membranes," b, "connecting membrane," widening previous to self-division; 32, Pleurosigma; 33, Synedra; 34, Coscinodiscus; 35, Triceratium; 36, Amphitetras.

The forms are not accurately drawn to scale, but are for the most part magnified about four hundred diameters.

Presented by H. C. Woodward

A BOTANICAL EXCURSION IN MY OFFICE.

BY PROF. HORATIO C. WOOD, JR., M. D.

PROBABLY most of the readers of the NATURALIST have, at some time or other in the last five years, owned, or at least been interested in aquaria. If what happens in Philadelphia may be taken as an index, many such observers of water-life have been pestered by a minute growth, which seems to flourish alike on plant or stick, on the living and dead. Last winter and spring the writer of this article had a small aquarium, which, as far as plants were concerned, was stocked chiefly with the *Ceratophyllum*, or hornwort, which, as is well known, possesses a vast abundance of finely dissected, twig-like leaves. Glancing one day at his water-garden, he noticed on these little cylindrical divisions a fine hazy fringe, scarcely to be perceived except by allowing the light to shine through the vessel containing the plant. Now this fringe, this nebulous garment clothing the hornwort, was the minute growth alluded to, which, though not strictly parasitic, not feeding on the plant to which it is attached, is, in most cases at least, associated with a sickly state of the larger plants, and certainly detracts from their beauty when viewed with the unaided eye, as in aquaria. But let us take our forceps, break off one

of these little twigs, place it on a glass slide, put over it the cover, and carry it to our microscope. For this examination, a power of about one hundred diameters is the most satisfactory, say an $\frac{8}{10}$ or $\frac{2}{3}$ objective. Let me place the object on the stand, adjust the light and focus, and now peer through the eye-glass, and lo! our scarcely perceptible prize starts into view as a huge subaquean forest, or rather cane-brake, with great leafless stems; here and there more sparse and open, here and there more close and impenetrable.

A wonderful land is this we have entered upon,—a land more strange than ever was dreamed of by Eastern romance. It has not only a vastly diversified flora, but also myriad animal forms.

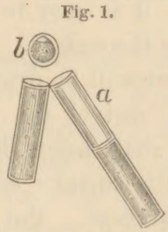
If time and space would allow, we might watch the little groups of Vorticellas, making, by their rapidly-moving cilia, numerous whirlpools, which, to many of the inhabitants of the drop of water, are as fearful as ever maelstrom was to ocean wanderer; for down in the centre of each miniature whirlpool lurks their destruction, towards which the current resistlessly forces them when once within its grasp. Perhaps a huge many-armed hydra might be found lurking in the thickets, or the jelly-like, formless mass of an Amœba writhe itself into ever-varying shapes before us. But we must pass by rotifers, infusoria, entomostracans, arachnids,—all the marvellous animal inhabitants to be seen,—as well as the various diatoms, desmids, and other plants, save the species which is the predominant feature of the scene we have been looking at.

The secret of the intense interest excited by these microscopic objects in any naturalist who has once fairly entered upon the study of them is the fact, that here we

are brought, as it were, face to face with the greatest of all mysteries—*life;* here we see it in its simplest expression, and are able to watch all its processes, to perceive every movement, and, in fact, come as close to the force or forces which constitute life, as the chemist in his laboratory, or electrician in his study, to the forces whose action they investigate. The study of infusoria or of microscopic algæ is not merely, as in most natural history studies, one of form and relation, but rather is it the study of life.

The scope of this paper is not such as to allow anything more than an entrance into this subject just far enough to glance at the beautiful prospect beyond. The plant itself is one of those simple forms which prefigure some variety of vegetable tissue, as seen in higher plants. It is composed of a number of cells placed end to end (Fig. 1), so as together to form a filament.

Fig. 1.



Zoöspore escaping, still surrounded with gelatinous material. *a*, cell in which it was formed; *b*, zoöspore, surrounded with its primary gelatinous envelope.

Let us pause a moment here to learn what a vegetable cell is, if we do not already know. The microscopist has given the name of *cell* to little vesicles, closed spheres, cylinders, or some other hollow forms, which his investigations have taught him, compose the animal and vegetable creation. Mayhap the reader of this article has, at some time in his summer saunterings, sat beneath a giant oak, and, peering into the water rippling at his feet, watched the little green mosses waving in the stream; or, stooping to pick up a pebble, has noticed the dark lubricous stratum on its surface. How different do these seem from the tree that shades him! Yet in their essence

they are the same. That scarcely perceptible speck on the quartz is a vast assemblage of little plants, composed each of but a single vesicle or cell; whilst the oak that towers above is nothing but a vast assemblage of such cells united into a single plant.

All plants, from the lowest to the highest, then, consist of cells, which are essentially the same throughout the whole vegetable kingdom. Let us take a cell of the plant before us, and examine it as a specimen of the vegetable cell.

In the first place, on its exterior we find a dense, but transparent coating, resistant to external force, and apparently structureless. Examine it with our highest powers, and still it is structureless, a homogeneous, perfect membrane, without pores or any interruptions whatever. Yet it is easy to prove that water and various fluids can pass through it. Place the cell in a dense syrup, and the water will be drawn out of it so rapidly, that the contents will shrivel up. Again; the contents of the cell are, as we shall know directly, composed largely of a substance which shrinks and hardens under the action of various substances. Put a plant in diluted acid, or strong alcohol, and see how the contents gather themselves together; or surround it with a solution of iodine, and see how soon the change of color in the most central part betrays the presence of that element. Such experiments as these prove that although the cell wall is absolutely homogeneous, destitute of all pores, yet fluids can pass through it. You see how, in the very onset, we are led into one of life's processes, *osmosis*, as it is technically called; but we must pass it by.

Let us try a little microscopic chemistry. Put a filament on a clean slide, and allow a watery solution of

iodine (dissolved by means of iodide of potassium) to flow round it. Then add a drop of sulphuric acid, and see ! the transparent, colorless outer wall has become of a decided bluish or purplish tint. This is the test for *Cellulose*, a substance identical with starch in its constitution, of which the outer wall of *all vegetable cells is composed.* When a plant wishes to store up its material for future use, it throws it into the form of little insoluble granules (*starch*), which are deposited in the cells in various storehouses,—sometimes underground stems, sometimes roots, sometimes leaves, sometimes other parts are selected. When the plant wants to move its material from place to place, it converts it into *dextrine*, which is soluble, and therefore capable of being transported. But when the material is to be finally disposed of, stored away, then it is made to take the form of *cellulose*.

Within the cell, lying immediately against the outer wall, is a thin, gelatinous, scarcely perceptible layer, which is colored brown by iodine, and coagulated and rendered more apparent by alcohol, sulphuric acid, and various reagents; this is the so-called *primordial utricle*, an albuminoid, homogeneous mass, in which much of the life-activity of the cell resides. Inside of this is a semi-fluid mass which is very complex in its constitution, and different at different times. The essential parts of it are *protoplasm* and *chlorophyl.* The former of these is probably identical with the primordial utricle, and shows its wonderful formative power. Chlorophyl is the green coloring matter of plants. It is chlorophyl containing protoplasm, which alone stands between all animate creation and death by starvation. For it is this alone which possesses the marvellous, almost creative power of seizing the inorganic elements and compounds of the earth and

air, and changing them into organic principles capable of life. But to do this, *light* is necessary; it is only by the aid of that force that the chlorophyl can awaken into life the clod and breeze. Without light,—

> "The world were void,
> The populous and the powerful were a lump
> Seasonless, herbless, treeless, manless, lifeless,
> A lump of death,—a chaos of hard clay."

Somewhere in the protoplasm is generally to be found a spot of great refractive power, the *nucleus;* in the cell before us mayhap we can find it close to the wall, maybe it is absent. The nucleus is nothing more or less than a little solid protoplasmic ball. Much importance is assigned to it by most authorities, and in fact it, when present, plays a very important role in the life-history of the cell. But in these algæ it is often absent, and the truth seems to be, that the primordial utricle, nucleus, and general protoplasm are identical in constitution and formative powers. In other words, that they are different manifestations of the same substance.

Now let us place one of our filaments under a high power and examine it closely. Under a $\frac{1}{5}$ objective, we will plainly perceive a very curious phenomenon going on inside of some of the cells. Notice among the general semifluid contents a number of minute dark specks or dots; these are minute granules of protoplasm. See! they are in active motion,—some are busy travelling from one end of the cell to the other, and all along it they are passing one another. But the mass of them are collected in two groups at the ends of their cells; all of them busy bustling about in all directions amongst themselves, reminding one of a hive of bees about to settle.

We have thus in our little plant had a sight of a process, which, variously modified, is probably present in all

vegetable cells during some period of their active life. To these protoplasmic movements the name of *Cyclosis* has been given. Among the higher plants, the hairs of the stamens of the *Tradescantia Virginica*, or Spiderwort, are favorite subjects for the study of Cyclosis.

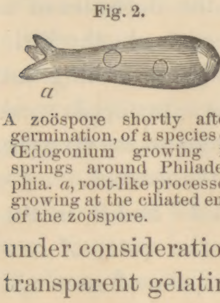
It is well known, that, in our ordinary flowering plants, there are two distinct methods of continuing the species. In the one case, there is a peculiar system of organs provided, which are in a measure antagonistic to the growth of the individual, and which produce seed, little bodies capable of renewing the life of the species; in the other case, certain portions of the ordinary nutritive organs of plants are set apart to reproduce the species. Thus in our common potato, by means of the flower, with its stamens and pistils, seed is produced; but, at the same time, portions of the underground stem become storehouses of vital force and starch, to serve as material out of which that force may obtain its building stores. Other familiar instances of this changing of the destinies of a part, are seen in the so-called bulbous roots, in the little aerial bulblets of the Tiger-lily,—all of them nothing but ordinary leaf-buds gorged with nutritive materials, and made the depository of vital force, in order to survive the death of the individual, and perpetuate the species.

As it is in the highest plants, so do we find it in the lowest. Unity in diversity seems to be the motto of creation; the broader we extend our studies, the oftener will we find the same ideas outcropping in different forms.

In the little confervoid growth under consideration, then, there are two distinct plans by which the species is perpetuated. The first is by a setting apart of certain ordinary nutritive parts of the plant, the other the specialization of a peculiar set of organs.

Let us study the former of these. Imagine our plant under the microscope, just as some one or more of its cells are to be sacrificed for the production of a new life. Watch that cell. See the endochrome, or green contents, gathering itself by an imperceptible motion into a condensed mass at the distal end of the cell. Now a separation is evidently taking place between this cell and the next at its distal end. Slowly they part from one another, remaining attached at one corner, so as to open like a hinge until the sundered parts, instead of being in one continuous line, lie side by side more or less parallel to one another, and a free opening is left at the end of the cell. Slowly the mass of endochrome continues to move, so slowly, that, even with a very high power, the motion is imperceptible. Perchance the outlet seems too narrow for it, and, in twisting itself out of it, the plastic mass assumes various shapes constricted in the middle where the orifice is. It continues, however, to advance, until at

Fig. 2.



A zoöspore shortly after germination, of a species of Œdogonium growing in springs around Philadelphia. *a*, root-like processes growing at the ciliated end of the zoöspore.

Fig. 2, *e*

Zoöspore killed to show its cilia.

last it is out of the cell in the free ocean around it. (Fig. 1.) It now recovers very quickly its shape, and is a bright green, globular or oval mass, with a little transparent spot at one end. As I have seen the species under consideration, this little ball is at first coated with a transparent gelatinous material, which rapidly dissolves off in the water. Let us keep our eye still fixed on the ball. See! the coating is nearly gone, and, is it true? the little ball begins to rock without apparent cause. Now it rocks faster and faster, and now it is gone out of the field like an arrow. Here it comes back, moving hither and yon, now very rapidly, now with a slow laterally rolling

motion. The plant has given birth to an offspring possessing apparently the peculiarly animal power of spontaneous motion. Let us now place a little solution of iodine or laudanum so that it will come in contact with our little moving body, and in a moment motion ceases, —we have killed it!

Let us now carefully arrange our light, illuminating the stage a little obliquely, put on our $\frac{1}{5}$ objective, adjust it for the glass cover, and see if we cannot discover the cause of the motion. Do you not see a circle or crown of long, lax, streak-like particles attached around the bright transparent space before spoken off. These are *cilia*, fine threads of condensed protoplasm. If during life one of these motive bodies is placed in a liquid containing very fine particles, as a dilute solution of India-ink or gamboge, and watched, constant currents will be seen to be produced by these cilia, which are in such rapid motion that they cannot be otherwise detected. It is, then, by virtue of the constant lashing of the cilia, that the little body moves, just as a boat moves by means of the scull. The movement of the cilia themselves is not a voluntary one; it is a form of the protoplasmic movements, of which cyclosis is one type.

Let us take our motive body, killed by means of the iodine, and add sulphuric acid to it; if cellulose be present, a bluish or purplish color will be produced. But there is none. In other words, our little body is composed simply of protoplasm and chlorophyl; it is a cell without a wall. To these moving bodies the name of zoöspore is given. If you watch a living zoöspore, in a little while its motion ceases, its cilia drop off, and it surrounds itself with a cellulose wall.

In most plants allied to the species under consideration,

from the position of the cilia (Fig. 2) there grow, during this process of germination, little root-like processes which attach themselves to some anchorage, but I have not been able to detect them in the aquarial inhabitant. The cell, having acquired a wall, and thus perfected itself, now begins to elongate; by and by it undergoes cell division, and thus divides itself in its length into two cells, which grow and divide, and by repetitions of this process, the filament is formed, that which we noticed at first. This plant belongs to the genus *Œdogonium*, the species of which are arrangeable into three sets; first, those in which the single filament produces both male and female organs; secondly, those in which male and female organs are produced in distinct filaments; thirdly, those in which the female filaments produce, besides the regular zoöspores, others which, in germinating, grow into peculiar dwarf plants, in which are formed the male germs. These three sets are known respectively as *monœcious*, *diœcious*, and *gynandrosporous* plants; the term androspore being given to the zoöspore, whose function is to grow into the little dwarf male plant. The Œdogonium of the aquarium belongs to the gynandrosporous division.

Besides these zoöspores the Œdogonia produce, by means of a specialized reproductive system just alluded to, a spore or seed which is known as a *resting spore*. In our plant this is produced as follows: a cell in the main filament begins to enlarge, and, at the same time, a communication is opened between it and the next proximal cell, whose endochrome is emptied into it. The two consolidated endochromes now contract themselves into a roundish ball in the swollen cell, the sporangia or spore-case. About this time several of the *androspores* (Fig. 3) attach

themselves generally on the emptied cell (Fig. 3), sometimes on the sporangium, and soon grow into a peculiar two-celled little plant. The base of the first of these cells is enlarged into a roundish, disk-like part, which is attached to the anchorage, and is known as the *foot.* It is the distal of the two cells in which are formed the male germs, the so-called *spermatozoids.* These are little bodies very similar to the zoöspores, but much smaller, and almost destitute of color. They are similarly ciliated, and have similar powers of locomotion.

Fig. 3.

A portion of a female plant with its spore just fertilized, and a dwarf male plant on the emptied cell. *a*, dwarf male plant; *b*, sporangium with its contained spore; *c*, opening through which spermatozoids enter; *d*, cell whose endochrome has been used in making the spore; *e*, spermatozoids (out of proportion in regard to size).

About the time that they are perfected, there is formed a lateral opening in the proximal or lower part of the sporangium of the resting spore. Through this orifice one or more of these spermatozoids enters and impregnates the endochrome, which contracts itself still more, and matures into the fully formed resting spore. During its maturation its green color changes into a reddish-brown, and it acquires two coats, the outer of which is very thick and provided with a curious spiral band or marking. (Fig. 5.)

Fig. 4.

Young dwarf male plant magnified about 1,000 diameters. *a*, foot; *b*, main body of the primary cell, with granular protoplasm in very active motion,—direction of the currents shown by arrows; *c*, newly-formed cell, very delicate, scarcely perceptible above.

The exact way in which germination of the resting spores takes place in the genus

Œdogonium, has never been determined. In the allied genus *Bulbochæta*, the resting spore finally breaks up into zoöspores, which grow into the plant in the same way as other zoöspores.

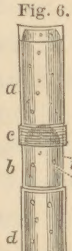
Fig. 5.

Portion of female filament with spores. *a*, immature; *b* and *c*, mature, showing spiral band.

If we examine our filament closely, we will find it terminated by a long, exceeding delicate, bristle-like hyaline point, composed of cells whose walls are so delicate, as to be scarcely perceptible with very high powers, and at the end apparently consisting simply of primordial utricle, though I confess never to have accurately determined this by micro-chemical tests. Again, if we look at some of the large cells of the filament closely, we will find near their distal end one, two, three, or more streaks surrounding them like so many collars. Let us look still more closely. Why! such cells evidently have their wall beyond the first streak or line thickened, in fact bear on their upper ends little caps, as it were, the lines being in the caps. The causes of these two phenomena, the hyaline point and the little caps, are to be found in the peculiar methods of growth of the Œdogonia. The larger cells increase by a variety of *cell multiplication by division*. Cell multiplication by division is almost the only way in which all vegetable growth takes place. The process, as it ordinarily occurs, may be outlined in a few words. If a cell, about to undergo it, contains a nucleus, the first change takes place in that nucleus; a constriction can be seen encircling and increasing in depth, until the nucleus is divided into two. When this has taken place, a doubled reflection from the primordial

utricle grows inwards, and, dividing the protoplasm and contents more and more completely, finally meets in the centre, and the single cell has been divided into two, each half of the original size. These small cells now increase in size by an interstitial growth of their cell-wall until they reach their full size, when, perchance, the process recommences. Sometimes a globular cell will divide into three, four, or more parts, but the process is essentially the same. In *free cell formation*, the protoplasm of a cell condenses into a varying number of little masses, which, whilst lying free in the interior of the mother cell, secrete, each around itself, a cellulose wall. In this way is formed a number of perfect cells, enclosed in, but independent of, the original cell, by whose dissolution they are finally set free.

Fig. 6.

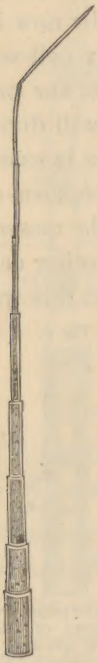


Two cells taken from a species of Œdogonium growing in the neighborhood of Philadelphia, not the aquarial one. *a*, cell in which division is about to take place above,—the dark line or streak showing; *b*, young cell bearing the remains of old cell (*c*) on it; *e*, its endochrome; *w*, its newly formed cellulose wall; *d*, old cell from which it has separated.

But let us return to our little plant and observe together a cell about to divide. The first noticeable change is the appearance of a dark streak around the cell near the distal end. At the position of this streak outgrowths take place from the primordial utricle as just described, and divide the old cell into two parts, the upper being much the smaller. (Fig. 6.) Watching the dark streak just spoken of, in a little while it begins to widen into a trench, and still continues to widen; the upper smaller division is growing by an elongation of the primordial utricle at the line of separation of the two parts. As the primordial utricle grows, it bears the old cellulose wall, like a cap upon its end; and, when it secretes its own proper cellulose wall, the

latter is of course inside of this. When the newly formed cell has attained its full size, it recommences the process again. The dark line now appears just below the edge of the old cap, and gives origin to the edge of the second cap, that of the former remaining apparent as a dark line. Again the process is gone through, and a third cap is formed, the margins of the first and second persisting. And so repetition after repetition, until a cell is formed bearing on its end a cap which is ringed with half a dozen dark lines, and composed of as many layers of cellulose. The dark rings of course mark the edges of the successively cut off ends of cells. If there be six such lines, cell division has taken place six times since the original was formed. (Fig. 6.)

Fig. 7.



End of a filament, showing hyaline point.

Fig. 8.

Perfected spore of the species from which Fig. 6 is taken.

Whilst the cells near the base are thus lengthening the filament by their increase, the end cell seems to grow by a sort of out-pushing of the primordial utricle from the central part of the fore end. This makes a little cylinder, which is soon cut off from its parent cell by a partition, secretes a cellulose coat, and then pushes out a new shoot from its free end, just as itself was formed. By a repetition of this, a series of cells is made, each of which is smaller than the proximal one; and, finally, the filament is drawn out into a fine hyaline point. (Fig. 7.)